Competing Against Entrenched Technology: Implications for U.S. Government Policies and Fuel Cell Development

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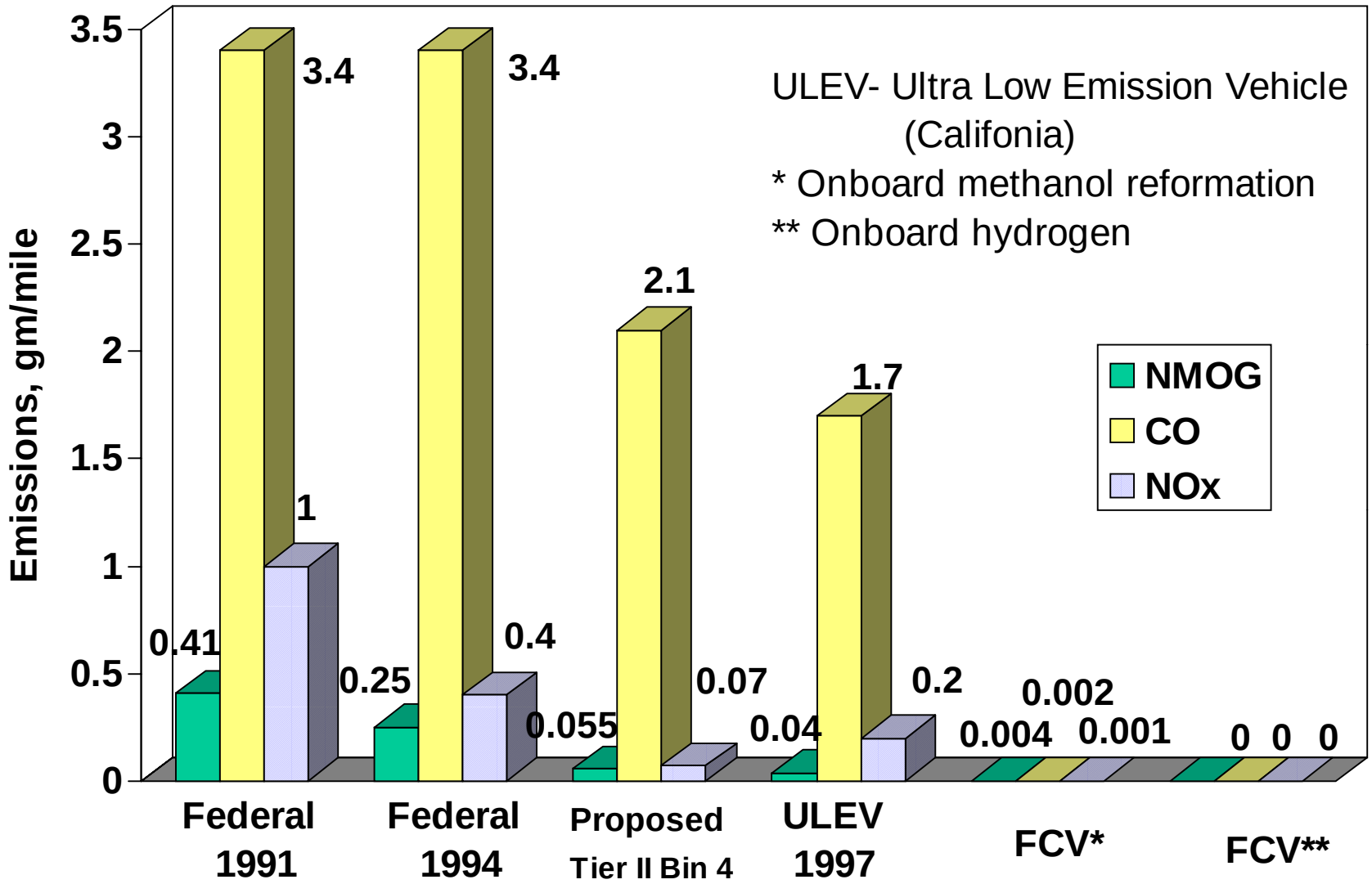
Factors Driving U.S. Technology Policies for Vehicles and Fuels

- **Energy security**
  - Transportation accounts for 1/4 of total energy use
  - Transportation uses 2/3 of all oil and is 97% dependent on oil
  - Economic impact of growing oil imports
  - The potential for oil supply disruptions -- “shocks”
- **Vehicle emissions, especially urban pollution**
  - 40% of volatile organic compounds
  - 49% of nitrogen oxides
  - 77% of carbon monoxide
  - Particulates and toxics are of increasing concern
- **And lately, global warming potential**
  - 26% of total greenhouse gas emissions
- **Others: sustainability, safety, lifestyle, etc.**

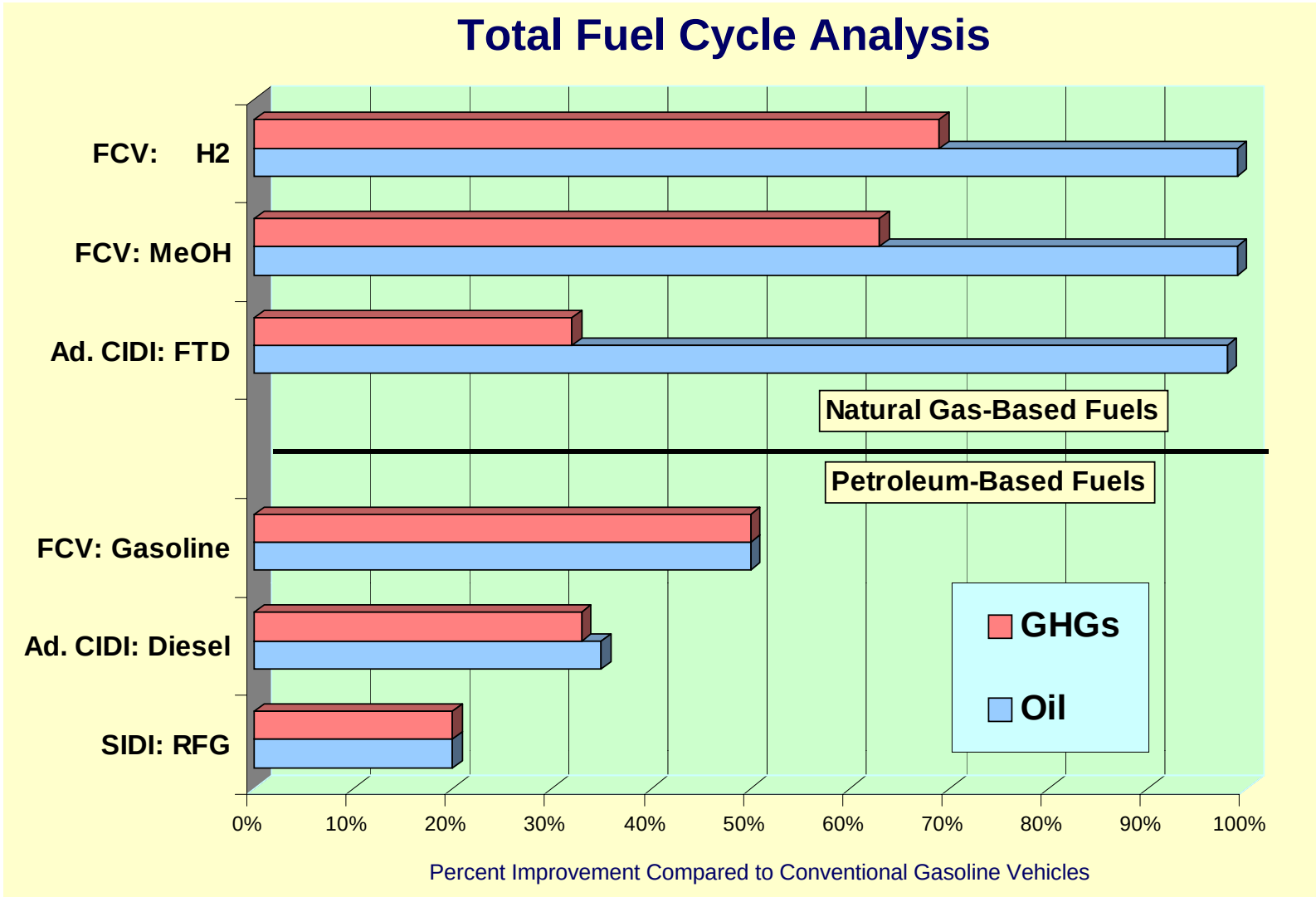
The Impetus for Fuel Cell Vehicle Development Is Due to Its Potential Benefits

- "Zero" or near-zero-emission vehicle
- Very high energy efficiency
- Low greenhouse gas emissions
- Shift to electric drivetrains
- Compatible with a renewable fuels strategy
- Long-term role in a hydrogen economy

One of the Most Appealing Benefits of Fuel Cells Is Its Very Low Emissions



Fuel Cells Also Offer Considerable Oil and Greenhouse Gas Benefits



The Value of Energy and Emissions Benefits Diminish As Conventional Vehicles Improve

Compare an 80-mpg fuel cell vehicle (100,000 mile life) to

- **a 25-mpg car meeting current Tier I standards**
- **a 40-mpg passenger car meeting the proposed Tier II standards**
- **a 30-mpg light-truck meeting Tier II (bin 7) vs 60-mpg fuel cell**

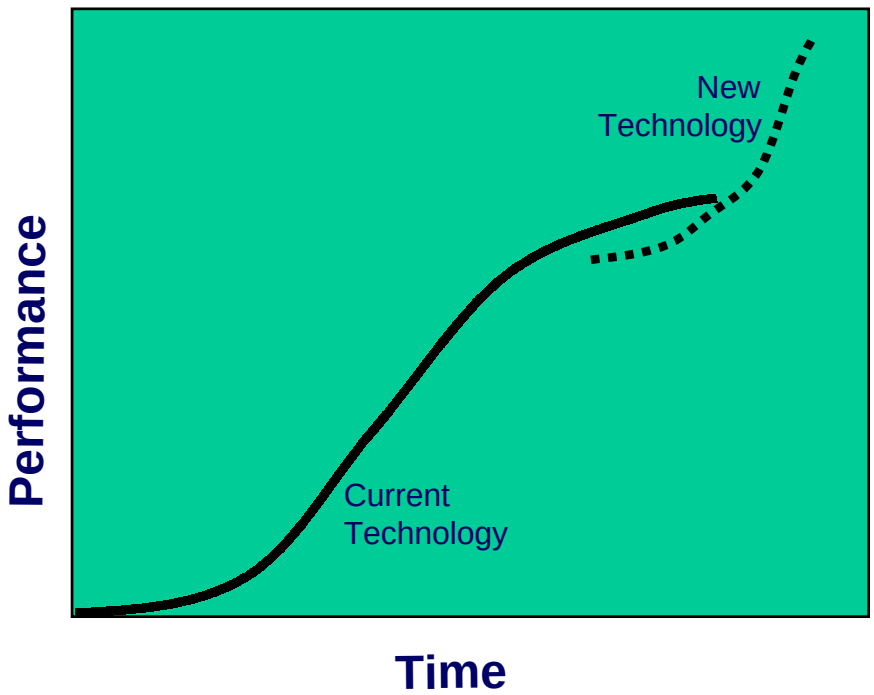
	Fuel Cell vs Tier I Car	Fuel Cell vs Tier II Car (Gasoline)	Fuel Cell vs Tier II Lt Truck (Diesel)
Criteria Pollutants	$ 900	$ 100	$ 200
Greenhouse Gases	$1200	$ 600	$ 500
Petroleum	$2800	$1300	$1700
Total Benefits Per Vehicle	$4900	$2000	$2400

Caveats

1) Emission-reduction benefits are location dependent
2) Benefits are greater for light truck substitution than for passenger cars
3) Costs are not considered in meeting air quality standards
4) Under the proposed Tier II Standards, if manufacturers produce vehicles in Bins 6 and 7, then near-zero-emission vehicles may be needed for a NOx offset

General Framework for Successful Transitions or Technological Discontinuities

Successful transitions (introduction and displacement) occur when:



- Older technologies reach the limits of improvement

  or

- Costs of improving existing technology exceeds costs of adopting the new

  OR

- New technologies offer new services or benefits that the consumer values

  or

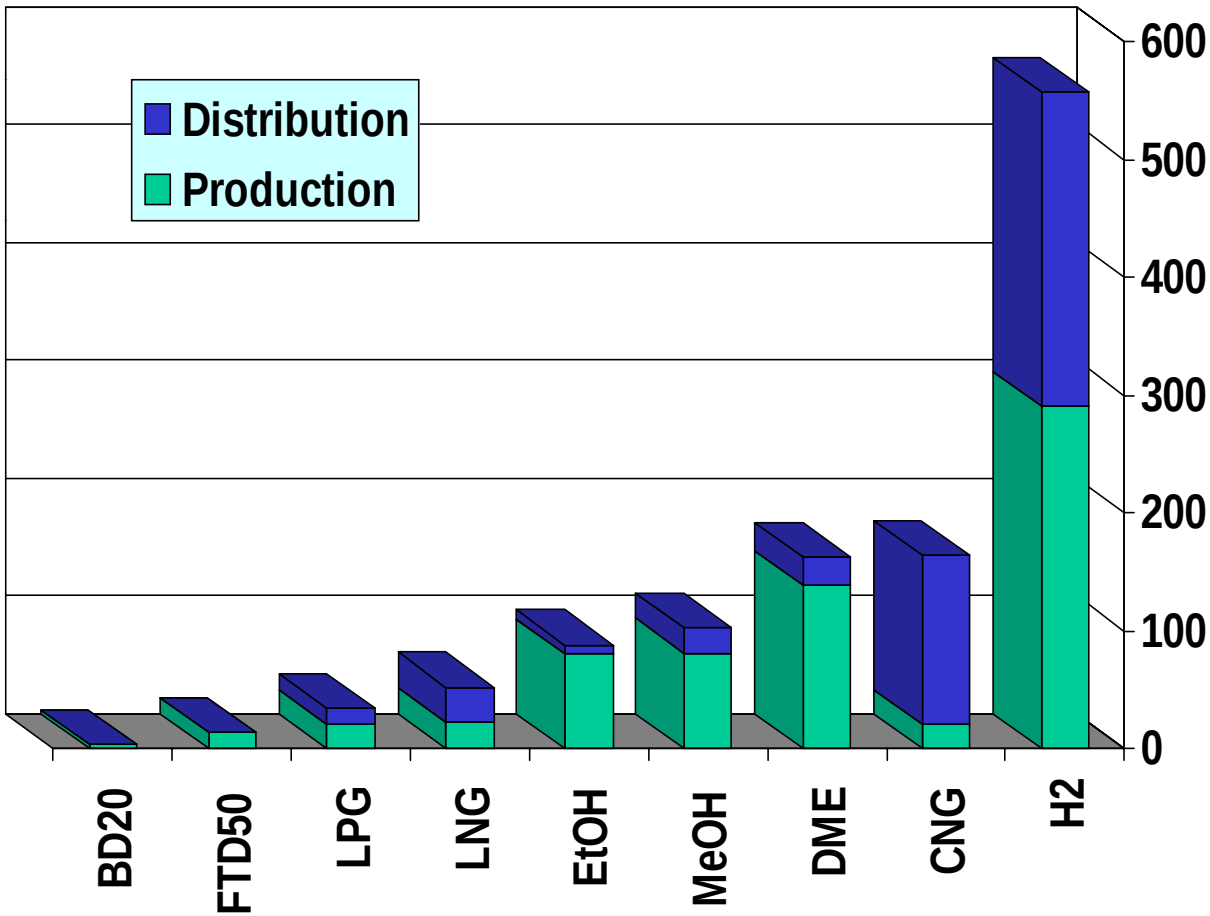
- The new technology is "transparent" (no shortcomings) while conveying societal benefits

Question: Where are fuel cells and conventional engines/fuels on the S-Curve?

Are Fuel Cells Poised to Replace Conventional Motor Vehicle Engines?

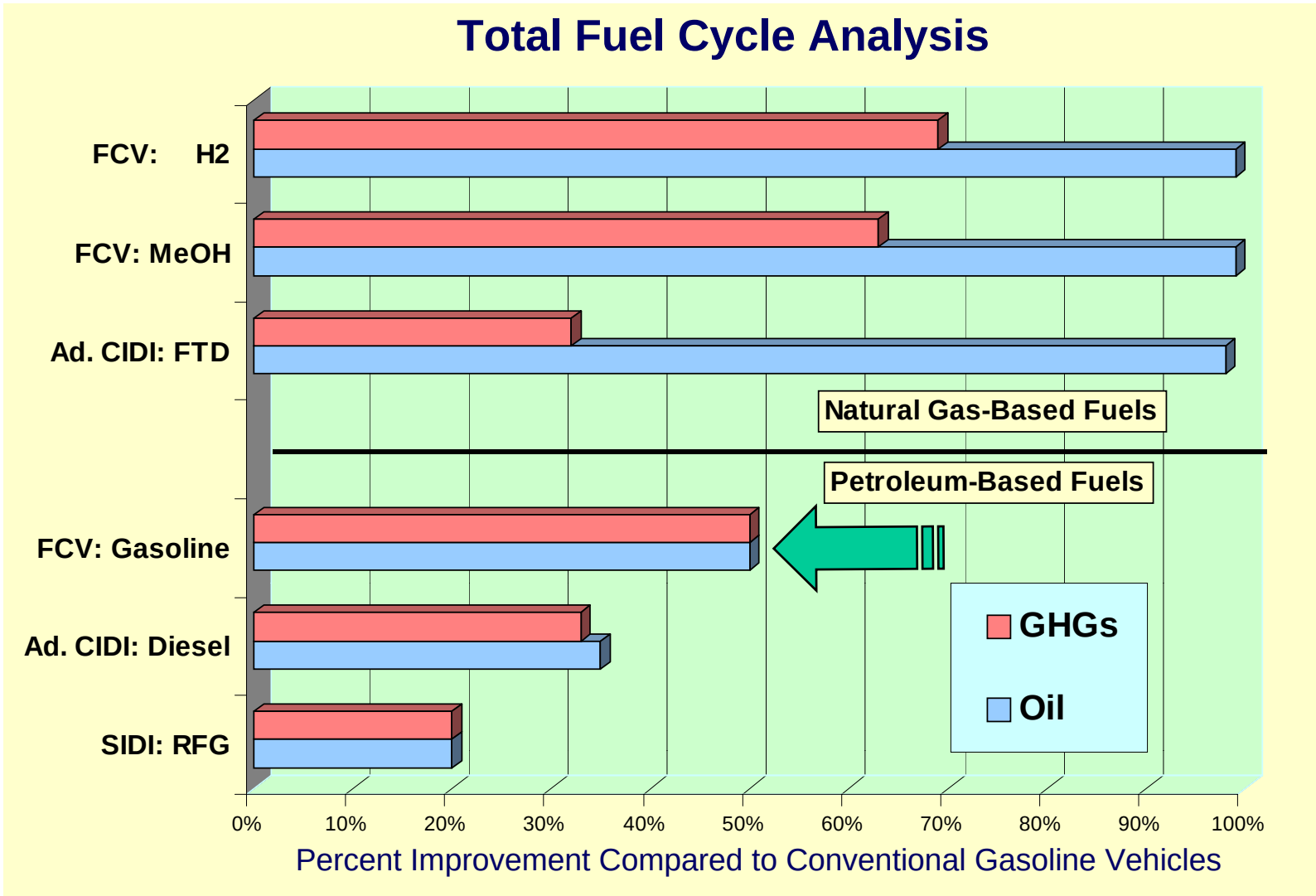
- Have conventional engines reached the limits of improvement?
  - In efficiency?
  - In emissions?
  - In fuel flexibility
- Is it more costly to continue with existing engines than adopt fuel cells?
- Do fuel cells offer the consumer new or valued services/benefits?
- Can fuel cell vehicles achieve “transparency”?

If Fuel Cell Vehicles Require Gaseous Fuels, Then Infrastructure Costs Will Be High



Production and Distribution Cost of
New Fuels for 3X Vehicles, 2007-2030 (10^9 $)

Fuel Cells Operating on Gasoline Have Benefits That Are Not Insignificant

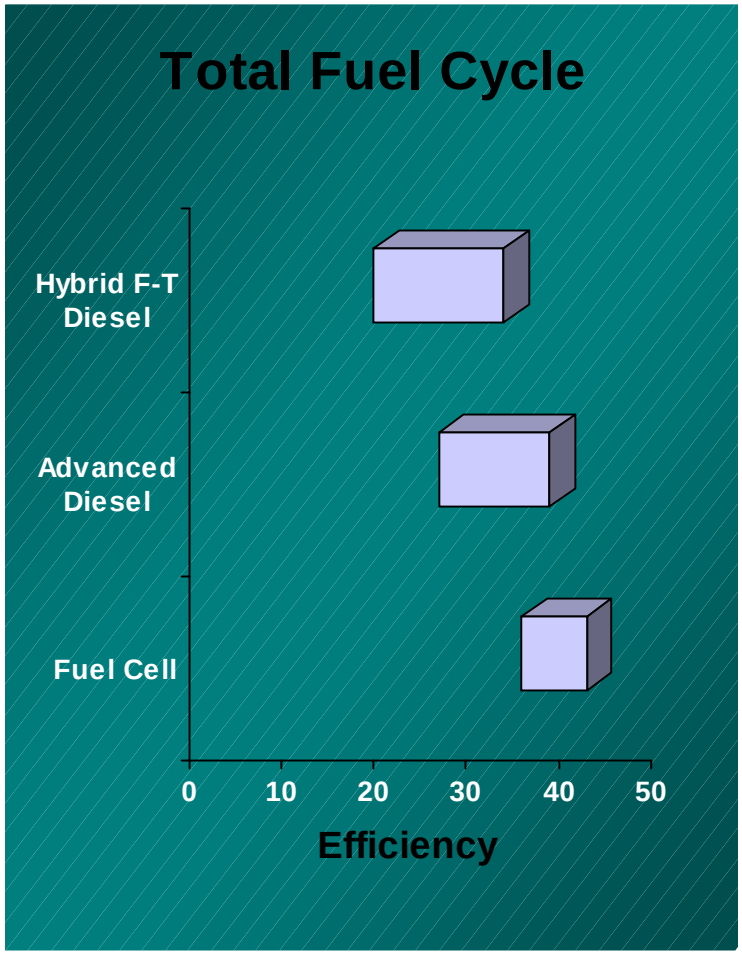


Should We Count on Anything Other Than Gasoline (or Diesel) for the Transition?

- **Fuels industry resistance to non-petroleum fuels**
  - Investments in clean, conventional fuels
  - Loss of marginal demand
- **The market failure of alternative fuels**
  - Lack of transparency
  - Infrastructure cost
  - Consumer refueling cost
  - Low volume
- **Do fuel cells really need new fuels for the <u>transition</u>?**

Is the Diesel a Serious Threat to the Fuel Cell?

- **Total fuel cycle efficiencies**
  - Fuel cell efficiencies are the highest among the options
  - Advanced diesel using petroleum could have similar efficiencies
  - Fischer-tropsch fuel offers emissions benefits but is more energy intensive to refine
- **Emissions standards will still be a hurdle for diesels**
- **Delphi forecast:**
  - Significant diesel by 2010
  - Rapid decline in diesels by 2020; growth in fuel cells



What Are the Implications of Competing Against Entrenched Technology

- **For government policy**
  - Where national benefits are significant, R&D is an appropriate government role
  - History of alternative fuels has shown the problems of premature market intervention
  - Additional government roles may be appropriate as technology matures
- **For fuel cell developers**
  - Pay attention to conventional fuels for the transition
    - Loss of efficiency compensated by infrastructure savings
    - Potential role for solid oxide fuel cell
  - Identify fuel cell attributes that manufacturers value
  - Identify market niches that consumers value